

Exhibit A

**Draft Patent Application Last
Modified on 15 August 2000**

193517US8

TITLE OF THE INVENTION

ULTRA WIDE BANDWIDTH NOISE CANCELLATION MECHANISM AND METHOD

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CROSS-REFERENCE TO RELATED PATENT DOCUMENTS

The present document contains subject matter related to that disclosed in commonly owned, co-pending application Serial No. 09/078,616 filed May 14, 1998, entitled ULTRA WIDE BANDWIDTH SPREAD SPECTRUM COMMUNICATIONS SYSTEM (Attorney Docket No. 10188-0001-8); Serial No. XXX,XXX filed August 7, 2000 entitled ELECTRICALLY SMALL PLANAR UWB ANTENNA (Attorney Docket 10188-0005-8); Application Serial No. 09/563,292, filed May 3, 2000 entitled PLANAR UWB ANTENNA WITH INTEGRATED TRANSMITTER AND RECEIVER CIRCUITS (Attorney Docket 10188-0006-8); Application Serial No. XX/XXX,XXX filed _____, entitled ULTRA WIDE BANDWIDTH SYSTEM AND METHOD FOR RADIO FREQUENCY INTERFERENCE CANCELLATION (Attorney Docket 192504US8); Application Serial No. XX/XXX,XXX filed _____, entitled ULTRA WIDE BANDWIDTH NOISE CANCELLATION MECHANISM AND METHOD (Attorney Docket 193517US8); Application Serial No. 60/217,099 filed July 10, 2000 entitled MULTIMEDIA WIRELESS PERSONAL AREA SYSTEM NETWORK (WPAN) PHYSICAL LAYER SYSTEM AND METHOD (Attorney Docket 194308US8PROV); Application Serial No. XX/XXX,XXX filed _____, entitled SYSTEM AND METHOD FOR BASEBAND REMOVAL OF NARROWBAND INTERFERENCE IN ULTRA WIDE BAND SIGNALS (Attorney Docket 194381US8); Application Serial No. XX/XXX,XXX, filed _____, entitled MODE CONTROLLER FOR SIGNAL ACQUISITION AND TRACKING IN AN ULTRA WIDEBAND COMMUNICATION SYSTEM (Attorney Docket 194588US8); Application Serial No. XX/XXX,XXX filed _____, entitled ULTRA WIDEBAND COMMUNICATION SYSTEM WITH LOW NOISE PULSE FORMATION (Attorney Docket 195268US8); Application Serial No. XX/XXX,XXX filed _____, entitled ULTRA WIDE BANDWIDTH SYSTEM AND METHOD FOR FAST SYNCHRONIZATION (Attorney Docket 195269US8); Application Serial No. XX/XXX,XXX filed _____, entitled ULTRA WIDE BANDWIDTH SYSTEM AND METHOD FOR FAST SYNCHRONIZATION USING HADAMMARD CODES

(Attorney Docket No. 195270US8); Application Serial No. XX/XXX,XXX filed
entitled ULTRA WIDE BANDWIDTH SYSTEM AND METHOD FOR FAST
SYNCHRONIZATION USING SUB CODES SPINS (Attorney Docket 195272US8);
Application Serial No. XX/XXX,XXX filed _____ entitled ULTRA WIDE
5 BANDWIDTH SYSTEM AND METHOD FOR FAST SYNCHRONIZATION USING
MULTIPLE DETECTION ARMS (Attorney Docket 195273US8); Application Serial No.
XX/XXX,XXX filed _____ entitled AGILE CLOCK MECHANISM AND
METHOD FOR ULTRA-WIDE BANDWIDTH COMMUNICATION SYSTEMS (Attorney
Docket 195670US8); and Application Serial No. XX/XXX,XXX filed
10 entitled RANGE-BASED AUTOMATIC DEVICE REGISTRATION (Attorney Docket
195671US8), where each of the above-identified applications include at least one of J.
McCorkle and T. Miller as an inventor, and the entire contents of each of the above-identified
documents being incorporated herein by reference.

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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to radio receivers, transceivers, systems and methods
employing wireless digital communications using ultra wide bandwidth (UWB) signaling
techniques, and other communication waveforms. More particularly, the present invention
20 relates to multi-mode communication systems in which one of the modes employs UWB
waveforms.

Description of the Background

UWB waveforms are used in is a form of communication in which energy is spread in
frequency over a much greater bandwidth than with conventional narrowband communication
25 systems such as television broadcast systems, or even traditional spread-spectrum
communication systems. For a discussion of UWB communications as well as other UWB
systems, see the above-identified related patent documents.

Figure 1 is a generalized spectral plot showing energy verses frequency for how UWB
compares with conventional schemes. As seen, a conventional narrowband communications
30 signal NB3 is shown to occupy a relatively small amount of frequency. A television signal
occupies a larger bandwidth and is representative of one of the widest bandwidth signals that
is still characterized as a conventional narrowband signal. A signal spectrum from a
conventional spread-spectrum signal SS2 occupies a greater bandwidth, at a lower power

spectral density (PSD, which is a measure of energy per hertz). A UWB signal occupies a much greater bandwidth, and, as can be seen, also has a lower PSD than either the narrowband communication signal NB3 or the spread-spectrum communication signal SS2.

As recognized by the present inventor, UWB receivers are often subject to self-interference as a result of a local oscillator used within the receiver having radiated emissions that fall "in band" and are coupled through the receive antenna. Moreover, in direct conversion receivers (without intermediate frequencies), there could be a problem of the local oscillator producing a radiated emission that is coupled back through the antenna and serves as a self-jamming signal. Conventional techniques for eliminating this problem are to employ a significant amount of shielding around the local oscillator circuitry to avoid direct radiation from the circuitry and to minimize the opportunity for feedback loops to exist within the receiver, thus giving rise to the self-interference.

However, as recognized by the present inventor, in a UWB receiver, because the bandwidth is so broad, it is common to employ a direct conversion receiver architecture. Accordingly, when there is local oscillator leakage (radiated or conducted), that leakage often manifests itself either as direct radiated emissions or in some way coupled into the front-end circuitry so as to contaminate the intended energy coupled into the signal path.

One problem that arises when the emissions are radiated is that the emissions first reflect off moving objects near the antenna, such as individuals or devices. When these reflections are present, the reflected, emissions energy tends to vary somewhat in magnitude and phase. Accordingly, the unwanted self-noise is not usually constant, but time varying, thus causing a bias level of the receiver's detector to vary, making the detection process more complex and difficult in obtaining satisfactory performance. Moreover, the output of the conversion mixer, which is used for performing the direct conversion, will contain both the intended signal as well as the reflected signal, which is possibly added coherently with the intended signal, giving rise to a bias term. Because the unintended signals may come from reflections off moving objects, the bias term is not steady, but rather "noisy".

SUMMARY OF INVENTION

Consistent with the title of this section, only a brief description of selected features of the present invention is now presented. A more complete description of the present invention is the subject of this entire document.

In view of the above-identified limitations with conventional systems, an object of the present invention is to address the above-identified and other limitations of conventional systems.

Another object of the present invention is to provide a mechanism for self-canceling
5 noise generated from oscillators within a UWB receiver.

Another object of the present invention is to provide a multi-mode receiver that, at least in one mode, is configured to receive and process bi-polar UWB signals.

The foregoing and other objects and advantages of the invention will appear from the following description. In the description, reference is made to the accompanying drawings
10 which form a part hereof and in which there is shown by way of illustration, and not of limitation, a preferred embodiment. Such description does not represent the full extent of the invention. But rather the invention may be employed in different arrangements according to the breadth of the invention.

In one embodiment of the present invention, a clock generator is used to produce a
15 clock signal at a frequency higher than that required for any reception mode. The clock signal is then divided by a divider circuit to produce a clock signal that is particularly well suited for that particular mode of reception. When receiving UWB signals, the detector does not use an exact copy of the signal send from the transmitter to correlate with the received signal. Instead, the detector uses a predetermined number of inverted symbols so that the integration
20 result when combined with the received signal will tend to be zero.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a spectral plot that contrasts bandwidths of a narrowband signal, a spread-spectrum signal, and a UWB signal;

25 Figure 2 is a block diagram showing how a transceiver employing a UWB radio according to the present invention may facilitate wireless communications between different appliances and external communication networks by way of a residential gateway;

Figure 3 is a UWB transceiver according to the present invention;

Figure 3A is a block diagram of a transceiver embodiment of the present invention in
30 which the modulation scheme employed is able to manipulate the shape of UWB pulses;

Figure 4 is a block diagram of a self-canceling and multi-mode selecting receiver according to the present invention;

Figures 5A-5E show various waveforms regarding how a bias term is eliminated according to a method employed by the present invention;

Figure 6 is a flow chart showing one embodiment for selecting different modes of operation and performing self-interference cancellation;

5 Figure 7 is a flow chart showing another embodiment for determining a type of waveform to be received by the receiver and a mechanism for configuring a receiver to receive that waveform and for performing self-interference cancellation; and

Figure 8 shows a processor system upon which an embodiment of the present invention may be implemented.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A UWB receiver and/or transceiver employed by the present invention may be incorporated into a residential gateway 5200 as shown in Figure 2. The radio is particularly
15 well suited for limited range, broad bandwidth and high data rate communication. Consequently, a radio according to the present invention may be implemented in different consumer or other devices. Such devices would benefit by conveying information in a convenient and fast manner via wireless communications from one location to the next. Digital video recorders can communicate digitized video data to a residential gateway 5200
20 for distribution to some remote source over a carrier such as a cable provider, digital subscriber line, or microwave link, for example. Internet enabled appliances may convey information from the appliances to the remote location as shown. Voice over IP devices may employ the present invention to convey voice, or audio players such as MP3 players might use the present invention to convey audio, for example. Similarly, a receiver according to the
25 present invention may be employed in home automation and security operations where it would be beneficial to communicate information wirelessly, in a convenient fashion from one location to a central monitoring station for example. Games and other devices, where data is exchanged between different processors, can be conveniently handled by a radio employing the teachings of the present invention.

30 As can be seen, the operational environment for a system that employs the UWB receiver according to the present invention will often be in the presence of active indoor environments, such as a house or office space. In these environments, the transmitters will broadcast relatively low power levels, per hertz, and the communication channel will involve

mobile obstacles, such a people. Accordingly, energy coupled into the receiver's antenna will include dynamic multi-path components.

Figure 3 is a block diagram of a UWB transceiver. Alternatively the system may be implemented as a separate receiver 11 and transmitter 13. In Figure 3, there are three major components, namely receiver 11, radio controller and interface 9, and transmitter 13. The radio controller and interface 9 serves as an media access control (MAC) interface between the UWB wireless communication functions implemented by the receiver 11 and transmitter 13, and applications that use the UWB communications channel for exchanging data with remote devices.

Receiver 11 includes an antenna 1 that converts a UWB electromagnetic waveform into an electrical signal (or optical signal) for subsequent processing. The UWB signal itself may be any one of a number of UWB waveforms, including (1) bi-phase modulated signals (+1, -1,), (2) multilevel bi-phase signals (+1, +a, -a, -1), (3) quadrature phase signals (+1, -1, +j, -j), (4) multilevel quadrature phase signals (+1, j), (-1, j), (+a, -aj) . . . , (5) pulse position modulation (PPM) signals (same shape pulse transmitted in different candidate time slots), and (6) any combination of the above waveforms, such as bi-phase channel symbols transmitted according to a PPM signaling scheme.

The electrical signals coupled in through the antenna 1 are passed to a radio front end 3. Depending on the type of waveform, the radio front end 3 processes the electric signals so that the level of the signal and spectral components of the signal are suitable for processing in the UWB waveform correlator 5. The UWB waveform correlator 5 correlates the incoming signal with different candidate signals generated by the receiver 11 so as to determine when the receiver 11 is synchronized with the received signal. The agile clock 7 operates under control of the radio controller and interface 9 to provide a clock signal that is used in the correlation process performed in the UWB waveform correlator 5. Moreover, in the receiver 11, the UWB waveform correlator 5 aligns in time a particular pulse sequence produced at the receiver 11 with the receive pulse sequence that was coupled in through antenna 1. When the two sequences are correlated with one another, the UWB waveform correlator 5 provides high signal to noise ratio data to the radio controller and interface 9 for subsequent processing. In some circumstances the output of the UWB waveform correlator 5 is the data itself. In other circumstances the UWB waveform correlator 5 provides simply correlation results to the radio controller and interface 9, which itself determines when the receiver 11 is synchronized with the incoming signal. In selected embodiments, when synchronization is not achieved

(i.e., during a signal acquisition mode of operation), the radio controller and interface 9 provides a control signal to the agile clock 7 so as to adjust the phase and/or frequency of the agile clock's output, thus sliding a correlation window within the UWB waveform correlator 5 until locked. The radio controller and interface 9 is a processor based unit that is
5 implemented either with hard wired logic such as in an application specific integrated circuit (ASIC), or in a programmable processor.

Once synchronized, the receiver 11 provides data to the radio controller and interface 9 for use in an external process through a "data out" line. The external process may be any one of a number of processes performed with data that is either received via the receiver 11,
10 or transmitted by the transmitter 15 to a remote receiver. During a transmit mode of operation, the radio controller and interface 9 receives source data from an external source and applies the data to an encoder 21 of a transmitter 13, as shown. Furthermore, the radio controller and interface 9 provides a control signal to an agile clock 19 for use in identifying the signaling sequence of UWB pulses. In some embodiments, the receiver and transmitter
15 functions may use joint resources such as a common agile clock and/or a common antenna for example. The encoder 21 receives the data from the radio controller and interface 9 and preprocesses the data so as to provide a timing input for the UWB waveform generator 17 to produce UWB pulses encoded in time and/or shape to convey the data to a remote location.

The encoder 21 may provide some identification of the source from which the data
20 comes (such as user ID). In one embodiment, this user ID may be inserted in the transmission sequence as if it were a header of an information packet. In other embodiments, the user ID itself may be employed to encode the data in blocks, such that the receiver receiving the transmission would need to have *a priori* knowledge of the user ID in order to make sense of the data. The output from the encoder 21 is applied to a UWB waveform generator 17. The
25 UWB waveform generator 17 may produce a UWB pulse sequence of one of any number of different schemes. In one modulation scheme the data may be encoded by using the relative spacing of transmission pulses (PPM). In other UWB communication schemes where it is possible to manipulate the shape of the pulses, the data may be encoded by exploiting the shape of the pulses. Examples include, a binary phase signal set, quadrature phase signal set,
30 or even a multilevel signal set as it is in the case of multi-level bi-phase modulation or even multilevel quadrature phase modulation. Furthermore it should be noted that the present invention is able to combine the use of pulse position modulation with other modulation schemes that manipulate the shape of the pulses. In this way, more data bits may be

contained per channel symbol transmitted from the transmitter 13. There are numerous advantages to this approach including having a greater number of bits per hertz transmitted, as well as the possibility of reducing the amount of transmit power per channel symbol required to transmit a predetermined amount of data. The output from the UWB generator 17
5 is then provided to an antenna 15, which then transmits the UWB energy to a receiver.

Figure 3A is a block diagram of a transceiver embodiment of the present invention in which the modulation scheme employed is able to manipulate the shape of the UWB pulses. When receiving energy through the antenna 1 (or 15 when referring to Figure 3) the energy is coupled in to a transmit/receive (t/r) switch 27 which passes the energy to a radio front end 3.
10 The radio front end 3 filters, extracts noise and adjusts the height of the signal before providing the same to a splitter 29. The splitter 29 divides the signal up into one of n different signals and applies the n different signals to different tracking correlators 31₁-31_N. Each of the tracking correlators 31₁-31_N receives a clock input signal from a respective agile clock 7₁, 7_N from an agile clock 7 (or 19) as shown in Figure 3A. The agile clock 7₁, as well
15 as the other agile clocks, includes a phase and frequency adjustment as shown. The radio controller and interface 9 provides a control signal to the agile clock 7₁ for both phase and frequency.

During signal acquisition, the radio controller and interface 9 adjusts the phase input of the agile clock 7₁, in an attempt for the tracking correlator 31₁ to identify the match the
20 phase of the signal produced at the receiver with the phase of the arriving signal. When the receive signal and the locally generated signal coincide in time with one another, the receiver is synchronized with the received signal. Once synchronized, the receiver will operate in a tracking mode, where due to differences in clock phase and frequency, the agile clock 7₁ may be adjusted by way of a continuing series of phase adjustments. However, a feature of the
25 present invention is that if a predetermined number of phase adjustments occurs within a certain number of phase adjustment opportunities, the radio controller and interface 9 adjusts the frequency of the agile clock 7₁. The frequency is adjusted in this instance because it is clear from the pattern of phase adjustments that there is a frequency offset between the agile clock 7₁ and the clock used at the transmitter for sending the signal.

30 A feature of the transceiver in Figure 3A is that it includes a plurality of tracking correlators 31₁-31_N. By having a plurality of tracking correlators it is possible to not only achieve synchronization more quickly (i.e., by attempting to correlate by operating parallel sets of correlation arms), but also during a receive mode of operation, to resolve the different

multipath components of a signal. By resolving the different multipath signal components, it is possible when using waveshape modulation to use the different multipath signal components to reinforce the received signal, thereby improving signal to noise ratio.

The radio controller in interface 9 receives the information from the different tracking correlators 31₁-31_n and decodes the data as well as providing control signals for controlling the front end (control line not shown) and adjusting the synchronization and tracking operations by way of the agile clock 7, 19. Furthermore the radio controller and interface 9 serves as an interface between the communication link feature of the present invention and other higher level applications that will use the wireless UWB communication link for performing other functions. Some of these functions would include performing range-finding operations, wireless telephony, file sharing, etc.

On the transmit portion of the transceiver shown in Figure 3A, an agile clock 7₀ also receives phase and frequency adjustments for use in encoding a UWB waveform. Data is provided to an encoder 21, which in the case of a PPM embodiment, passes the data to the agile clock 7₀ for providing a predetermined time delay at which a pulse will be sent, which is a way for encoding the data into the transmitted waveform. When the shape of the different pulses are modulated according to the data, the encoder 21 provides the data as a way to select different shapes for generating particular waveforms in a waveform generator 17 as shown. For example, the data may be grouped in multiple data bits per channel symbol. The waveform generator 17 then produces the requested waveform at a particular time as indicated by the agile clock 7₀. The output of the waveform generator is then filtered in filter 23 and amplified in amplifier 25 before being transmitted via antenna 1, 15 by way of T/R switch 27.

Figure 4 is a block diagram that shows in more detail how the self-noise cancellation feature and mode selector are employed according to the present invention. Either UWB signal energy or energy from another type of waveform (such as a Bluetooth waveform, as will be discussed) is received through antenna 2013. When the switch connected to the antenna is set to pass a signal through low noise amplifier (LNA), AGC, and stub circuitry 401 (which cancels unwanted, in-band radio frequency interference), the signal is at a proper signal level for direct conversion and detection. When the switch at the antenna is set to the other position, the LNA, AGC, and stub circuitry 401 are bypassed so that a direct path is provided into mixer 413 by way of switch 411.

A synchronization ("sync") phase agile clock 402 provides a steady 4.8 GHz output that may be used for reception of either UWB or Bluetooth signals (as one example of another waveform). Bluetooth signals employ a variety of modulation schemes that operate in the industrial-scientific-medical (ISM) band (2.4 to 2.5 GHz), detailed features of which are
5 discussed in "Specification of the Bluetooth System", v1.0b, December 1, 1999, Core-Specification-Volume 1, Profiles Specification-Volume 2, the entire contents of which being incorporated herein by reference, and being available at www.bluetooth.com.

As can be seen, the 4.8 GHz clock output of the clock 402 is provided to a first divide circuit 403, which divides the clock output by a predetermined integer amount M, where M=2
10 for a Bluetooth signal (in one embodiment, although another amount may be used as well), to provide a mixing signal to the mixer 413 for conversion of the waveform desired. When switch 411 is switched to connect with pulse forming network (PFN) 407, the receiver is adaptably configured to receive UWB signals according to the present invention. For example, the divide circuit 405 is set to divide the clock signal by N, where N=3, so as to
15 provide a 1.6 GHz signal. This 1.6 GHz signal is provided to the pulse forming network 407, which also receives the data/code from an external source and timing information from timers 423 so as to produce a series of UWB bi-phase signals to be mixed in mixer 413 with the incoming RF signals.

A copy of the signal from the PFN 407 is also applied to a mixer 417. The mixer 417
20 is also fed with a copy of the incoming signal after being further filtered with stub 415 that excises the clock frequency. Thus, at least the main term of the clock frequency is suppressed in the error channel. After the mixer 417, the resulting error signal is integrated and sampled in integrator/sampler 419 before being digitized in A/D error circuit 427.

The output of the mixer 413 is DC blocked by the capacitor, as shown, before being
25 applied to integrator/sampler circuit 421 that also receives timing information for timers 423. An output of the integrator/sampler circuit 421 is digitized in a main digitizer 425 before being applied to a mixer 430. The integrator/sampler circuit also provides a sample clock at 200 MHz to minimize phase differences between detection sampling and "baseband" waveform sampling in A/D main 425. The output of the A/D main is combined in Mixer 430
30 with the error signal for subsequent processing, decoding, and detection.

Both dividers 403 and 405, as well as switch 411, cooperate with one another under control of a processor (not shown, although it could be included in PFN 407) to configure the

receiver to operate either in a UWB mode of operation or in another receive mode of operation such as Bluetooth.

A risk of direct conversion reception is mitigated by the use of sync phase agile clock 402 that operates at a higher frequency than the frequency that is actually applied to mixer 413. This way, energy that is produced by the sync phase agile clock 402, which may couple to a leakage path L1 into antenna 2013, is kept to a minimum. Using the divider circuits 405 and 403, it is possible to limit the line length as well as the active circuitry required to produce a signal that falls "in band".

Another technique employed by the present invention to mitigate the effect of self-interference is shown in the waveforms of Figures 5A-5E. Figure 5A shows an exemplary RF UWB signal that may be received by the receiver at the output of mixer 413. As can be seen, the pattern of received wavelets shows two non-inverted wavelets 501, 502, followed by an inverted wavelet 503, followed by a non-inverted wavelet 504. If the signal provided by the PFN 407 to the mixer 413 (in Figure 4) provides the same phase signals as the received RF signals, then the signal provided by the PFN 407 would appear as shown in Figure 5B. When integrating, after the output of the mixer 413, the waveform input to the integrator/sampler 421 is shown in Figure 5C. As can be seen, all the energy has the same sign, so that the integration result monotonically increase (in a perfect case) and thus always increase above 0 volts before detection is made.

As recognized by the present inventor, the local oscillator leakage problem is a limitation of this positively sloped integration approach. If there is leakage along the leakage path L1 that couples into the system, an unintended in-band leakage signal is generated that influences the integration process. Thus, a leakage signal appears to be coherent with the desired signal and tends to bias-up the integration signal. The mixer 413 itself will have a bias term that tends to drift. Thus, if the energy through the leakage path L1 moves as a function of the reflection obstacle with which it interacts, it causes fairly significant "noisy" integration results. Noisy integration causes an increased likelihood of bit-errors, thus limiting performance.

Another technique for counteracting the self-interference is to invert the second "pair" of wavelets as shown in Figure 5D. Figure 5D shows that the third and the fourth wavelets (or more generally a predetermined number and spacing of wavelets) are inverted with regard to the set shown in Figure 5B. The second wavelet pair 520 in Figure 5D is inverted. As a consequence, the integration waveform as shown in Figure 5E will have two positive terms,

followed by two negative terms. This way, if energy does leak back through the antenna, the leakage will tend to integrate to 0. Consequently, the risk of a floating bias is reduced by this self-leveling technique because the bias term will tend toward zero when aggregated over multiple symbols. Thus, using the inversion technique shown in Figure 5D reduces the effect of bias terms as a result of leakage path and the bias terms that may be present with mixer
5 413.

Figure 6 is a flow chart showing a process for selecting different modes of operation and performing self-interference mitigation according to the present invention. The process begins in step S105 where a controller employed in a receiver according to the present
10 invention identifies a default mode of operation, which in the present embodiment is set to a UWB mode of operation. Then in step S107, a query is made regarding whether another mode (or in an alternative embodiment, a signal indicating that it has identified a received signal as a non-UWB signal) is selected. If the response to the inquiry in step S107 is negative, the process proceeds to step S111. However, if the response to the inquiry in step
15 S107 is affirmative, the process proceeds to step S109 where the mode is switched to the other mode of operation before proceeding to step S111. In step S111, the signal is received in the selected mode. In step S113, a self-interference mitigation operation is performed. Subsequently, the signal is decoded in step S115 and the process ends.

In step S111, the PFN purposefully produces predetermined groups of wavelets that
20 are inverted with respect to the wavelets that are expected to be received. Preferably, the number of inverted wavelets is equal in number to an adjacent set of non-inverted wavelets so that the integrator will tend to produce a zero integration result when integrating over both the inverted wavelets and non-inverted wavelets.

Figure 7 shows an alternative technique where the waveform itself is detected in order
25 to determine what mode of operation in which this receiver will operate. The process begins in step S2101 where signal energy is received. Then in step S2103, the particular type of waveform contained at the received signal energy is detected. In step S2105, an inquiry is made whether the detected waveform is a UWB bi-phase signal. If the response to the inquiry in step S2105 is affirmative, the process proceeds to step S2113 after first having the self-
30 interference mitigation process invoked in step S2202. Alternatively, the self-interference cancellation can be performed in step S2113.

However, if the response to the inquiry in step S2105 is negative, the process proceeds to step S2107 where a feature of the waveform is detected. In step S2109, the detected

feature is compared with a saved set of candidate waveforms. After step S2109, the process proceeds to step S2111 where the identity of the waveform is identified. In step S2113, the receiver is configured based on the detected waveform to form the appropriate RFI extraction and signal processing operation. Subsequently, the signal is decoded in step S2115 and the process ends.

The UWB transceiver of Figures 3 and 3A may be used to perform a radio transport function for interfacing with different applications as part of a stacked protocol architecture. In such a configuration, the UWB transceiver performs signal creation, transmission and reception functions as a communications service to applications that send data to the transceiver and receive data from the transceiver much like a wired I/O port. Moreover, the UWB transceiver may be used to provide a wireless communications function to any one of a variety of devices that may include interconnection to other devices either by way of wired technology or wireless technology. Thus, the UWB transceiver of Figure 3 may be used as part of a local area network (LAN) connecting fixed structures or as part of a wireless personal area network (WPAN) connecting mobile devices, for example. In any such implementation, all or a portion of the present invention may be conveniently implemented in a microprocessor system using conventional general purpose microprocessors programmed according to the teachings of the present invention, as will be apparent to those skilled in the microprocessor systems art. Appropriate software can be readily prepared by programmers of ordinary skill based on the teachings of the present disclosure, as will be apparent to those skilled in the software art.

Figure 8 illustrates a processor system 1401 upon which an embodiment according to the present invention may be implemented. The system 1401 includes a bus 1403 or other communication mechanism for communicating information, and a processor 1405 coupled with the bus 1403 for processing the information. The processor system 1401 also includes a main memory 1407, such as a random access memory (RAM) or other dynamic storage device (e.g., dynamic RAM (DRAM), static RAM (SRAM), synchronous DRAM (SDRAM), flash RAM), coupled to the bus 1403 for storing information and instructions to be executed by the processor 1405. In addition, a main memory 1407 may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by the processor 1405. The system 1401 further includes a read only memory (ROM) 1409 or other static storage device (e.g., programmable ROM (PROM), erasable PROM (EPROM), and electrically erasable PROM (EEPROM)) coupled to the bus 1403 for storing static

information and instructions for the processor 1405. A storage device 1411, such as a magnetic disk or optical disc, is provided and coupled to the bus 1403 for storing information and instructions.

The processor system 1401 may also include special purpose logic devices (e.g., application specific integrated circuits (ASICs)) or configurable logic devices (e.g., simple programmable logic devices (SPLDs), complex programmable logic devices (CPLDs), or re-programmable field programmable gate arrays (FPGAs)). Other removable media devices (e.g., a compact disc, a tape, and a removable magneto-optical media) or fixed, high density media drives, may be added to the system 301 using an appropriate device bus (e.g., a small system interface (SCSI) bus, an enhanced integrated device electronics (IDE) bus, or an ultra-direct memory access (DMA) bus). The system 1401 may additionally include a compact disc reader, a compact disc reader-writer unit, or a compact disc juke box, each of which may be connected to the same device bus or another device bus.

The processor system 1401 may be coupled via the bus 1403 to a display 1413, such as a cathode ray tube (CRT) or liquid crystal display (LCD) or the like, for displaying information to a system user. The display 1413 may be controlled by a display or graphics card. The processor system 1401 includes input devices, such as a keyboard or keypad 1415 and a cursor control 1417, for communicating information and command selections to the processor 1405. The cursor control 1417, for example, is a mouse, a trackball, or cursor direction keys for communicating direction information and command selections to the processor 1405 and for controlling cursor movement on the display 1413. In addition, a printer may provide printed listings of the data structures or any other data stored and/or generated by the processor system 1401.

The processor system 1401 performs a portion or all of the processing steps of the invention in response to the processor 1405 executing one or more sequences of one or more instructions contained in a memory, such as the main memory 1407. Such instructions may be read into the main memory 1407 from another computer-readable medium, such as a storage device 1411. One or more processors in a multi-processing arrangement may also be employed to execute the sequences of instructions contained in the main memory 1407. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions. Thus, embodiments are not limited to any specific combination of hardware circuitry and software.

As stated above, the processor system 1401 includes at least one computer readable medium or memory programmed according to the teachings of the invention and for containing data structures, tables, records, or other data described herein. Stored on any one or on a combination of computer readable media, the present invention includes software for
5 controlling the system 1401, for driving a device or devices for implementing the invention, and for enabling the system 1401 to interact with a human user. Such software may include, but is not limited to, device drivers, operating systems, development tools, and applications software. Such computer readable media further includes the computer program product of the present invention for performing all or a portion (if processing is distributed) of the
10 processing performed in implementing the invention.

The computer code devices of the present invention may be any interpreted or executable code mechanism, including but not limited to scripts, interpretable programs, dynamic link libraries, Java or other object oriented classes, and complete executable programs. Moreover, parts of the processing of the present invention may be distributed for
15 better performance, reliability, and/or cost.

The term "computer readable medium" as used herein refers to any medium that participates in providing instructions to the processor 1405 for execution. A computer readable medium may take many forms, including but not limited to, non-volatile media, volatile media, and transmission media. Non-volatile media includes, for example, optical, magnetic disks, and magneto-optical disks, such as the storage device 1411. Volatile media
20 includes dynamic memory, such as the main memory 1407. Transmission media includes coaxial cables, copper wire and fiber optics, including the wires that comprise the bus 1403. Transmission media may also take the form of acoustic or light waves, such as those generated during radio wave and infrared data communications.

Common forms of computer readable media include, for example, hard disks, floppy disks, tape, magneto-optical disks, PROMs (EPROM, EEPROM, Flash EPROM), DRAM, SRAM, SDRAM, or any other magnetic medium, compact disks (e.g., CD-ROM), or any other optical medium, punch cards, paper tape, or other physical medium with patterns of
25 holes, a carrier wave, carrierless transmissions, or any other medium from which a system can read.
30

Various forms of computer readable media may be involved in providing one or more sequences of one or more instructions to the processor 1405 for execution. For example, the instructions may initially be carried on a magnetic disk of a remote computer. The remote

computer can load the instructions for implementing all or a portion of the present invention remotely into a dynamic memory and send the instructions over a telephone line using a modem. A modem local to system 1401 may receive the data on the telephone line and use an infrared transmitter to convert the data to an infrared signal. An infrared detector coupled
5 to the bus 1403 can receive the data carried in the infrared signal and place the data on the bus 1403. The bus 1403 carries the data to the main memory 1407, from which the processor 1405 retrieves and executes the instructions. The instructions received by the main memory 1407 may optionally be stored on a storage device 1411 either before or after execution by the processor 1405.

10 The processor system 1401 also includes a communication interface 1419 coupled to the bus 1403. The communications interface 1419 provides a two-way UWB data communication coupling to a network link 1421 that is connected to a communications network 1423 such as a local network (LAN) or personal area network (PAN) 1423. For example, the communication interface 1419 may be a network interface card to attach to any
15 packet switched UWB-enabled personal area network (PAN) 1423. As another example, the communication interface 1419 may be a UWB accessible asymmetrical digital subscriber line (ADSL) card, an integrated services digital network (ISDN) card, or a modem to provide a data communication connection to a corresponding type of communications line. The communications interface 1419 may also include the hardware to provide a two-way wireless
20 communications coupling other than a UWB coupling, or a hardwired coupling to the network link 1421. Thus, the communications interface 1419 may incorporate the UWB transceiver of Figure 3 and/or Figure 3A as part of a universal interface that includes hardwired and non-UWB wireless communications coupling to the network link 1421.

The network link 1421 typically provides data communication through one or more
25 networks to other data devices. For example, the network link 1421 may provide a connection through a LAN to a host computer 1425 or to data equipment operated by a service provider, which provides data communication services through an IP (Internet Protocol) network 1427. Moreover, the network link 1421 may provide a connection through a PAN 1423 to a mobile device 1429 such as a personal data assistant (PDA) laptop
30 computer, or cellular telephone. The LAN/PAN communications network 1423 and IP network 1427 both use electrical, electromagnetic or optical signals that carry digital data streams. The signals through the various networks and the signals on the network link 1421 and through the communication interface 1419, which carry the digital data to and from the

system 1401, are exemplary forms of carrier waves transporting the information. The processor system 1401 can transmit notifications and receive data, including program code, through the network(s), the network link 1421 and the communication interface 1419.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope
5 of the appended claims, the invention may be practiced otherwise than as specifically described herein.

Claims

1. A UWB self-noise cancellation mechanism for reducing performance degradation as a result of self-generated noise, comprising:
- 5 a pulse forming network configured to produce a series of UWB bi-phase signals;
a mixer configured to combine said UWB bi-phase signals with an incoming RF UWB signal; and
an integrator configured to accumulate an output of said mixer, wherein
said pulse forming network is configured to produce a first set of bi-phase wavelets
10 and an adjacent second set of bi-phase wavelets, said first set of bi-phase wavelets oriented to have a same phase as a corresponding subset of wavelets in said RF UWB signal and said second set of bi-phase wavelets oriented to be inverted in phase from a corresponding subset of wavelets in said RF UWB signal.
- 15 2. A UWB self-noise cancellation mechanism as claimed in Claim 1, wherein:
the first set of bi-phase wavelets being two wavelets.
3. A UWB self-noise cancellation mechanism as claimed in Claim 1, wherein:
the first set of bi-phase wavelets and the second set of bi-phase wavelets having equal
20 number of wavelets.
4. A UWB self-noise cancellation mechanism in a UWB receiver, comprising:
means for producing a series of UWB bi-phase wavelets having a same phase as
corresponding portion of an incoming RF signal;
25 means for producing another series of UWB bi-phase wavelets having an opposite
phase as a corresponding portion of the incoming RF signal;
means for combining said series and said another series with said incoming RF signal
to produce an output; and
means for integrating said output over a length the corresponds with said series and
30 said another series such that an integration output being zero when said incoming RF signal is
aligned with said series and said another series.

5. A UWB mode selection mechanism for determining what type of waveform is being received by a receiver, comprising:

a clock signal generator configured to provide clock pulses at a predetermined rate;

a first divide circuit having a first predetermined integer amount by which said predetermined rate of clock pulses is divided;

a second divide circuit having a second predetermined integer amount by which said predetermined rate of clock pulses is divided; and

a switch configured to select an output of said first divide circuit when a UWB receive mode of operation is selected, and to select an output of said second divide circuit when another receive mode of operation is selected.

6. A UWB mode selection mechanism as claimed in Claim 5, wherein:

said predetermined rate being 4.8 GHz;

the first divide circuit having said first predetermined integer amount of 3; and

the second divide circuit having said second predetermined integer amount of 2.

7. A UWB mode selection mechanism in a radio front-end of a UWB receiver, comprising:

means for selecting a receive mode of operation;

means for providing clock pulses at a predetermined rate;

means for dividing said predetermined rate by an amount corresponding to a received mode selected by said means for selecting a receive mode of operation;

means for processing a received UWB signal with clock pulses provided by said means for dividing when said means for selecting selects a UWB mode of operation.

8. A UWB receiver comprising:

a UWB self-noise cancellation mechanism including

a pulse forming network configured to produce a series of UWB bi-phase signals,

a mixer configured to combine an output from said pulse forming network with an incoming RF signal, and

an integrator configured to accumulate an output of said mixer; and

a UWB mode selection mechanism including

a clock configured to produce input pulses at a predetermined rate,
a first divide circuit having a first predetermined integer amount by which said
predetermined rate of clock pulses is divided,
a second divide circuit having a second predetermined integer amount by
5 which said predetermined rate of clock pulses is divided, and
a switch configured to select an output of said first divide circuit when a UWB
receive mode of operation is selected, and to select an output of said second divide circuit
when another receive mode of operation is selected.

ABSTRACT OF THE DISCLOSURE

5 A mechanism and method for self-canceling noise generated in a UWB receiver and for providing multi-mode operation of the receiver. Noise is canceled by generating a set of wavelets in a same phase and another set with an opposite phase as the incoming signal, mixing the wavelets with the signal, and integrating the mix such that the integrated output tends to zero. The receiver can switch to multiple types of waveforms, thereby providing multi-mode operation. Exemplary embodiments of the switching between modes include a user-selected switch and a waveform-detection based switch.

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